

Does Warming Up With Wearable Resistance Influence Internal and External Training Load in National Level Soccer Players?

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Background: Adding wearable resistance (WR) to training results in superior performance compared with unloaded conditions. However, it is unclear if adding WR during warm-up influences training load (TL) in the subsequent session. The aim of this research was to track TL in soccer players during the transition from late preseason to early in-season and examine whether adding WR to the lower leg during a warm-up influenced TL measures during warm-ups and on-field training sessions after WR was removed.

Hypothesis: The addition of WR worn on the lower legs during an on-field warm-up would lead to decreases in relatively high-intensity external TL metrics, such as distance covered $>6.11 \text{ m}\cdot\text{s}^{-1}$ and acceleration and deceleration $>/<3 \text{ m}\cdot\text{s}^{-2}$ and increases in internal TL during the warm-up, yet would have little effect on the subsequent training session when WR was removed.

Study Design: Matched-pair randomized design.

Level of Evidence: Level 3.

Methods: A total of 28 soccer players were allocated to either a WR training (WRT = 14) or unloaded (control [CON] = 14) group. Both groups performed the same warm-up and on-field training for 8 weeks, with the WRT group wearing 200 g to 600 g loads on their lower leg during the warm-up. External TL was measured via global positioning system data and internal TL was assessed using session rating of perceived exertion (sRPE \times time per session).

Results: No statistically significant between-group differences ($P \geq 0.05$) were identified for any TL measurement during either warm-ups or training sessions. Lower leg WR resulted in trivial to moderate effects for all external TL metrics (-16.9% to 2.40% ; $d = -0.61$ to 0.14) and sRPE (-0.33% ; $d = -0.03$) during the warm-up and trivial to small effects on all external TL metrics (-8.95% to -0.36% ; $d = -0.45$ to -0.30) and sRPE (3.39% ; $d = 0.33$) during training sessions.

Conclusion: Warming up with lower leg WR negatively affects neither the quality and quantity of the warm-up nor the subsequent training session once WR is removed.

Clinical Relevance: Using WR on the lower leg during on-field warm-ups may be a means to “microdose” strength training while not unduly increasing TL. However, further research is needed to determine the influence of WR on strength qualities.

Keywords: football; monitoring; soccer; sport specific; training; transference

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It is commonplace for coaches and performance staff to measure team sport athletes' external and internal training load (TL) to manage stress and guide training adaptations. The outcome of training is determined by the internal response to external stimuli.²⁶ The importance of these measurements becomes apparent when considering that high TL can affect acute neuromuscular fatigue and impair lower body power development³⁸ and increase injury risk.⁴ As both external and internal loads have merit for understanding the athlete's TL, a combination of both may be important for monitoring training.²¹ That is, it is important to track whether prescribed physical training (ie, external TL) results in the desired training response (ie, internal TL) for an athlete.

External TL can be defined as the physical work completed by the athlete, measured independently of the athlete's internal characteristics.²⁶ In team sports, external TL is commonly measured using global positioning systems (GPSs) integrated with accelerometer technology.² These tools provide metrics calculated by positional differentiation, such as measures of total distance covered (or in specific speed bands), the number of efforts an athlete undertakes in various speed or acceleration bands, or estimated metabolic power.^{33,34} While external TL provides important information on the physical demands imposed on an athlete, it does not account for the internal response that the volume or intensity of work may have on athletes of different fitness levels, and therefore it cannot offer individual responses to training.

For an integrated approach to TL, internal and external TL should be used concomitantly.⁷ A common tool used to measure internal TL in field athletes is through the rating of perceived exertion (RPE).^{15,21} The RPE method is based on the understanding that athletes can inherently monitor the physiological stress their body experiences during physical activity.¹⁵ By multiplying RPE of a training session by the session duration (in minutes), Foster et al¹⁹ produced an internal TL metric aptly called session RPE (sRPE) that has been widely adopted for use in team sports.^{1,6,27,35} Another possible reason sRPE has been embraced in team sports is because it has been shown to be significantly correlated with objective external TL metrics such as GPS and accelerometer data^{11,31} and other internal TL measures such as heart rate markers⁹ and training impulse.¹

There are multiple facets to an athlete's training program, such as resistance training, on-field warm-ups, and on-field training sessions.³² The culmination of the different training sessions compound external TL and subsequently affect internal TL.²⁸ It is relatively straightforward to use external TL measurements, such as GPS data, to determine whether an athlete has performed more work from one session to the next. Combined with internal TL measurements, GPS can be used to develop a holistic load profile for an athlete.⁷ For example, modifying the volume or intensity of a warm-up influences both sRPE and physical performance, with greater external TL (in minutes) resulting in greater internal TL and poorer acute sprinting ability.⁴⁰ What is less clear is whether using novel resistance training techniques involving placing small loads on distal

segments of the body while performing the same warm-up or training session will influence either external or internal TL.

Traditional resistance training is beneficial for building maximal strength¹⁰ and tissue resilience,³⁷ yet lacks specificity with regard to on-field transference; particularly, specificity with regard to movement velocity.¹³ Therefore, based on the principle of training specificity, training methods should attempt to resemble the characteristics of sporting actions to enable optimal transference to on-field performance.¹⁴ Until recently, the idea of using wearable resistance (WR) on distal segments of the body while performing sport-specific movement training, that is, running, changing directions and jumping, was not pragmatic because of the cumbersome equipment involved.²⁹ With recent advancements, WR loads $\leq 1\%$ body mass can be affixed to the lower leg while performing high-velocity sport-specific movements with minimal to no disruption in technique.^{16,25,30} Furthermore, lower leg WR between 200 g and 600 g integrated into an 8-week warm-up program has been shown to significantly ($P \leq 0.05$) improve soccer players' 10- and 20-m sprint ability by 2% and enhance horizontal jumping by 6%.⁸ While understanding the performance effects of WR on overt performance gives us an indication of this training method for enhancing physical performance, it is unknown whether WR affects the external or internal TL while an athlete is performing his or her sport-specific training.

Given that measuring both external and internal TL are useful for athlete monitoring²¹ and that wearing WR during the warm-up can improve sprinting and jumping performance in soccer athletes,⁸ information regarding the effects of WR on the external and internal markers of TL in field-sport athletes may be of interest to coaches and performance staff. Accordingly, the intent of this study was to investigate whether wearing WR during a warm-up affects GPS or sRPE measures and whether any delayed effects would be present in the subsequent training session when WR was removed. It was hypothesized that the addition of WR worn on the lower legs during an on-field warm-up would lead to decreases in external TL metrics and increases in internal TL during the warm-up, yet would have little effect on the subsequent training session when WR was removed.

METHOD

Experimental Design

To identify whether adding WR into a warm-up program affected TL over an 8-week training cycle during late preseason and early in-season, a range of external and internal TL metrics were compared between matched-pair randomized groups, half the players wearing WR and half unloaded. U18 Argentinean First Division soccer players were matched on position and running speed to account for speed bands calculated via GPS and randomly allocated to a loaded WR (WR training [WRT]; $n = 14$) group or an unloaded group (control [CON]; $n = 14$) using a matched-pair randomized design. Players in both the WRT and the CON conditions performed the same warm-up and participated in the same soccer-specific training program for the

duration of the 8-week study. External TL was measured using GPS units with built-in accelerometers. Internal TL was measured using RPE, which was collected immediately (within 2 minutes) after each warm-up and 30 minutes after the end of training according to the procedures suggested by Foster.¹⁸ The sRPEs were obtained using the 10-point Borg scale. External and internal TL measures were compared between groups to understand whether using WR during an on-field warm-up influenced objective and subjective measures of TL both during the warm-up and, once removed, for the remainder of the training session. Players were familiar with using the procedures and devices utilized in the study.

Participants

A total of 28 national level U18 soccer players partaking in the Argentinean First Division Soccer Tournament volunteered to participate in this study (age, 17.1 ± 0.76 years; body mass, 69.0 ± 5.32 kg; height, 176 ± 6.18 cm). All players were part of the same team and had an average football training experience of 4.5 years. Permission was granted from the soccer club to perform analyses on training monitoring data obtained during 4 weeks of preseason, just prior to the start of the season, and extended into the first 4 weeks of early in-season in 2018. Participants were matched for physical characteristics of height and body mass, and by position and sprinting performance before being randomly allocated to either a WRT ($n = 14$; body mass, 70.0 ± 5.11 kg; height, 177 ± 6.24 cm) or an unloaded CON group ($n = 14$; body mass, 68.1 ± 5.54 kg; height, 175 ± 6.24 cm). Participants, and where appropriate, their guardians, were informed of the procedures, risks, and benefits of participating in this study, and signed informed assent/consent forms approved by Auckland University of Technology's Research Ethics Committee, in accordance with the Declaration of Helsinki. Respondents were excluded from this study if they did not attend at least 80% of the training sessions. The players were advised to maintain their normal diet for the duration of the 8 weeks. No injuries were reported as part of the training program.

Procedures

Both the CON and the WRT groups took part in the same training sessions composed of the same activities at the same relative intensities over an 8-week block during the last 4 weeks of preseason and first 4 weeks of in-season. A total of 19 training sessions were monitored between February and April of the 2018 competitive season. The monitored training sessions took place at least 24 hours between each other and were all performed on the same outdoor grass pitch at similar times of day (11:00 AM).

The warm-up protocols implemented for this research were the same as those used by Bustos et al.⁸ The warm-up program consisted of 3 sections: approximately 5 minutes of continuous moderate intensity running interspersed with bouts of dynamic stretching, 10 to 15 minutes of soccer-specific technical ball handling drills, and 5 to 8 minutes of high-intensity sprinting, jumping, and change of direction drills. After the warm-up, WR

was removed from the calves and the athletes performed their normal soccer-specific training program consisting of small-sided games, running exercises, and technical and tactical drills. Additional skill work and strength and conditioning sessions were matched between groups, and only on-field training sessions were included in this analysis. Ad libitum fluid consumption was permitted for the players during rest periods.

Wearable Resistance Loading

For the WRT group, WR was integrated into the athletes' normal on-field warm-up regimen via LILA Exogen calf sleeves (Sportboleh Sdh Bhd). The calf sleeves were made of a form-fitting Exoprene material fixed using Velcro straps on the proximal and distal segments of the garment. Each athlete's calf circumference was measured and the WR garments were fitted according to the manufacturer's sizing guidelines.³⁷ The WRT program consisted of progressively overloaded WR loads ranging from 200 g to 600 g placed on the posterior aspect of the athletes' calves, similar to Bustos et al.⁸ An overview of the 8-week cycle of WR can be observed in Table 1. Weighted panels were in 200-g increments, and total load for each trial was loaded in a neutral pattern, as seen in Figure 1.

External Training Load

Similar to previous research,^{11,20} the player's external load was monitored and quantified by means of portable GPS devices (K-Sport Universal SRL) operating at a sampling frequency of 10 Hz and incorporating a 100-Hz triaxial accelerometer. A device number was assigned to each player that was maintained throughout the investigation. Each player wore a special harness that enabled this device to be fitted to the upper part of his back. The GPS devices were activated 15 minutes before the start of each training session, in accordance with the manufacturer's instructions. The 10-Hz GPS devices recorded all on-field training sessions, and analysis was conducted on the warm-up and soccer-specific training sessions over the 8-week training cycle. After recording, the data were downloaded to a PC and analyzed using the software package K-Sport online (K-Sport Universal SRL). All the observed sessions were designed by the team's head coach and fitness trainer, who supervised all the training sessions. Data analysis included all the activities performed during the training sessions including the recovery periods. The indicators of external load were as follows: total distance covered; distance covered at speeds >4.44 m·s⁻¹; distance covered at speeds >6.61 m·s⁻¹; distances accelerating at >2 m·s⁻² and >4 m·s⁻²; distances decelerating at <-2 m·s⁻² and <-4 m·s⁻²; and distance traveled where metabolic power was >20 W/kg, and >55 W/kg.³³

Internal Training Load

Subjective data were measured through RPE using the Borg category ratio 10 scale.⁵ The players' internal load was monitored and quantified by means of sRPE. The sRPEs were obtained by having players rate their training perceived effort immediately (within 2 minutes) after each warm-up and 30

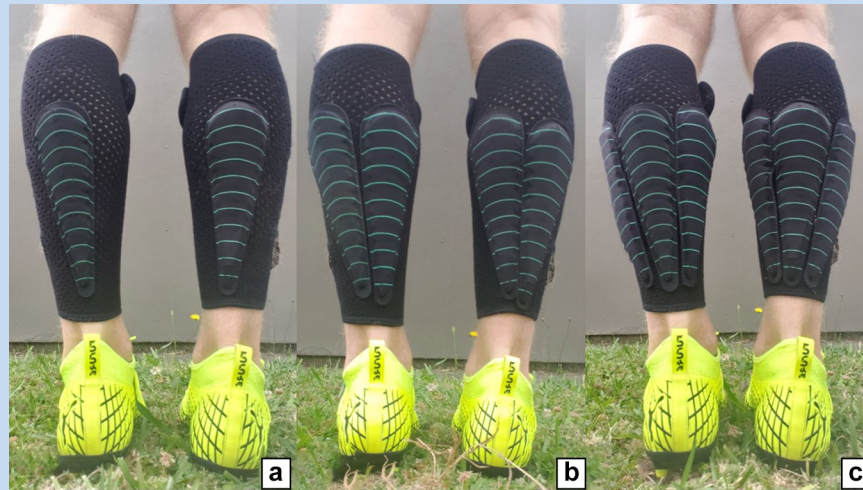


Figure 1. Example of calf loading patterns for (a) 200 g, (b) 400 g, and (c) 600 g.

Table 1. Periodized 8-week soccer-specific wearable resistance loading scheme

Weeks	Load, g	Position Relative to Leg/Knee
1	200	Posterior/proximal
2	200	Posterior/distal
3	400	Posterior/proximal
4	400	Posterior/proximal
5	400	Posterior/distal
6	600	Posterior/proximal
7	600	Posterior/distal
8	600	Posterior/proximal

minutes after the end of training according to the procedures suggested by Foster.¹⁸ The sRPE was multiplied by the total duration of either the warm-up or training session in minutes (time) (sRPE × time) to receive the training load for the warm-up or the entire training.

Statistical Analysis

Data were presented as mean ± SD. Normality was tested using Shapiro-Wilk test to determine any obvious effects and estimate the distribution of the data. Homogeneity of variance was tested using the Levene test. Comparisons between groups were assessed using independent-samples *t* tests. Mann-Whitney *U* tests were used to compare between groups where nonuniformity of error was present. Effect sizes (ES = mean change/pooled standard deviation of the sample scores) were

calculated to quantify the extent of the performance changes between groups.¹² ES of >1.2, 0.6 to 1.19, 0.2 to 0.59, <0.19 were classified as large, moderate, small, and trivial, respectively.^{12,23,24} Alpha was set at *P* < 0.05 and 95% CIs were used for all analyses. Statistical analysis was conducted using a custom Microsoft Excel spreadsheet (Version 16.0; Microsoft Corporation) and SPSS statistical software package (Version 25.0; IBM Corporation).

RESULTS

Comparison During Warm-up Session

Performance data and between-group comparisons during the warm-up are presented in Table 2. No significant differences were found between the groups for any external or internal load measurement during the warm-up. Compared with the CON, WRT had a moderate negative effect on total distance covered >6.11 m·s⁻¹, with all other effects being trivial or small. All between-group differences for the warm-up ranged from -16.9% to 2.40%.

Comparison During Training Session

Performance data and between-group comparisons during the training sessions are presented in Table 3. No significant differences were observed for measures of external or internal load between groups during the training component of the session. In addition, the training effect of WR on all measures of interest were trivial or small. Between-group differences during the training session ranged between -8.95% and 3.39% for all variables.

DISCUSSION

The main findings of this study were that WR did not significantly alter any external or internal measures of TL during either the warm-up or the subsequent training session.

Table 2 Total internal and external load comparison between the CON and WRT groups during warm-up

Load Metric	CON, Mean ± SD	WRT, Mean ± SD	% Difference, ^a Mean (95% CI)	Effect Size <i>d</i> , (95% CI)	Effect Size Descriptor
sRPE (AU)	145 ± 9.79	145 ± 18.4	-0.33 (-1.08 to 0.42)	-0.03 (-0.77 to 0.71)	Trivial
Total distance (m)	39449 ± 5053	40395 ± 8027	2.40 (1.43 to 3.37)	0.14 (-0.60 to 0.88)	Trivial
Distance >4.44 m·s ⁻¹ (m)	4225 ± 1541	3956 ± 1201	-6.38 (-8.21 to -4.55)	-0.20 (-0.94 to 0.55)	Small
Distance >6.11 m·s ⁻¹ (m)	718 ± 238	597 ± 152	-16.9 (-21.5 to -12.4)	-0.61 (-1.38 to 0.16)	Medium
Acceleration >2 m·s ⁻² (m)	2487 ± 511	2464 ± 569	-0.93 (-1.70 to -0.15)	-0.04 (-0.78 to 0.70)	Trivial
Acceleration >3 m·s ⁻² (m)	1019 ± 197	959 ± 219	-5.83 (-7.56 to -4.10)	-0.29 (-1.04 to 0.47)	Small
Deceleration <2 m·s ⁻² (m)	2075 ± 483	2011 ± 525	-3.10 (-4.20 to -2.00)	-0.13 (-0.87 to 0.61)	Trivial
Deceleration <3 m·s ⁻² (m)	767 ± 224	701 ± 207	-8.58 (-11.0 to -6.17)	-0.31 (-1.06 to 0.45)	Small
Mean power >20 W/kg (m)	6994 ± 1729	6746 ± 1605	-3.54 (-4.72 to -2.00)	-0.15 (-0.89 to 0.59)	Trivial
Mean power >55 W/kg (m)	1098 ± 289	1037 ± 296	-5.58 (-7.22 to -3.94)	-0.21 (-0.95 to 0.53)	Small

AU, arbitrary unit; CON, control group; sRPE, session rate of perceived exertion; WRT, wearable resistance training group.

^aPercentage (%) difference is the WRT load relative to the control group.

These findings partially support the hypothesis that most metrics would remain unaffected by WR during the warm-up and no effect would be evident during the unloaded training session.

Given that warm-ups are designed to adequately prepare athletes for the rigors of their sport,^{3,22,36} a concern of including WR into a program might be whether WR affects the quality and quantity of the warm-up. The addition of calf-loaded WR influences metabolic parameters¹⁷ during submaximal running and can therefore be a way to increase intensity. As intensity increases, the quality and quantity of the warm-up exercises may be compromised; however, neither external nor internal TL differed between the WRT and CON groups. This means that athletes using WR are able to sustain a similar running intensity and volume with calf-loaded WR over a training cycle. In fact, the accumulated load of adding WR into an 8-week warm-up improved sprinting and horizontal jumping performance in national level soccer players.⁸

Incorporating WR into a warm-up may help improve physical capabilities of athletes and not affect the quality or quantity of

their warm-up; however, consideration must be given to what happens to athletes during their subsequent training session, as it is quite possible that fatigue may be increased in the WRT group. The findings of this study showed no differences between the WRT and CON groups with regard to either external or internal TL for the sport-specific training session after WR was removed following the warm-up. This suggests that utilizing calf-loaded WR during the warm-up does not lead to detrimental effects on the quantity or quality of the rest of the training session.

Adding external load to distal segments of the body while performing high-intensity movements will result in increased work performed by the athletes using WR. The mechanical overload provided by loading the calf with 200 g to 600 g was sufficient enough to induce improvement in a number of physiological measures⁸, however, was also of appropriate intensity to not affect the quality and quantity of the remainder of the soccer sessions as quantified by GPS data and sRPE. While including WR into an on-field warm-up session may enhance athletes' physical capabilities⁸ and not affect their TL

Table 3. Total internal and external load comparison between the CON and WRT groups during training

Load Metric	CON, Mean ± SD	WRT, Mean ± SD	% Difference, ^a Mean (95% CI)	Effect Size <i>d</i> , (95% CI)	Effect Size Descriptor
sRPE (AU)	678 ± 82.2	701 ± 51.9	3.39 (2.21 to 4.57)	0.33 (-0.43 to 1.09)	Small
Total distance (m)	168060 ± 18468	167456 ± 19139	-0.36 (-1.15 to 0.43)	-0.03 (-0.82 to 0.75)	Trivial
Distance >4.44 m·s ⁻¹ (m)	21936 ± 4454	20011 ± 4008	-8.78 (-11.2 to -6.32)	-0.45 (-1.22 to 0.31)	Small
Distance >6.11 m·s ⁻¹ (m)	2569 ± 639	2339 ± 884	-8.95 (-11.5 to -6.45)	-0.30 (-1.06 to 0.46)	Small
Acceleration >2 m·s ⁻² (m)	9194 ± 1662	8879 ± 1645	-3.43 (-4.62 to -2.25)	-0.19 (-0.95 to 0.57)	Trivial
Acceleration >3 m·s ⁻² (m)	3514 ± 658	3378 ± 673	-3.87 (-5.14 to -2.59)	-0.20 (-0.96 to 0.55)	Small
Deceleration <2 m·s ⁻² (m)	7923 ± 1478	7529 ± 1549	-4.98 (-6.51 to -3.46)	-0.26 (-1.02 to 0.50)	Small
Deceleration < 3 m·s ⁻² (m)	2834 ± 650	2679 ± 682	-5.48 (-7.13 to -3.84)	-0.23 (-0.99 to 0.52)	Small
Mean power >20 W/kg (m)	35639 ± 6649	33189 ± 6246	-6.87 (-8.86 to -4.89)	-0.38 (-1.14 to 0.38)	Small
Mean power >55 W/kg (m)	3726 ± 753	3556 ± 857	-4.58 (-6.01 to -3.14)	-0.21 (-0.97 to 0.55)	Small

AU, arbitrary unit; CON, control group; sRPE, session rate of perceived exertion; WRT, wearable resistance training group.
^aPercentage (%) difference is the WRT load relative to the control group.

during sport-specific training sessions, it is unknown how this method will translate to external or internal TL during competition. In addition, no information was obtained on the technical and/or tactical activities of the players.

A possible limitation of this study was the short time gap between the finish of the warm-up and RPE collection. However, because of practical circumstance (commencement of training) it was impossible to adhere to any other guidelines. Our relatively small sample size might be problematic from a statistical standpoint; however, this is countered by having a highly trained group of 28 players over a relatively long training period.

Essentially, utilizing lower-leg WR resulted in trivial to moderate effects for all internal and external TL metrics during the warm-up and trivial to small effects during training sessions. Warming up with lower-leg WR negatively affects neither the quality and quantity of the warm-up nor the subsequent training session once WR is removed. Coaches might consider implementing WR into their on-field warm-ups as a time-saving strategy to “microdose” high-velocity strength training without affecting sport-specific training performance.

REFERENCES

- Alexiou H, Coutts AJ. A comparison of methods used for quantifying internal training load in women soccer players. *Int J Sports Physiol Perform.* 2008;3:320-330.
- Aughey RJ. Applications of GPS technologies to field sports. *Int J Sports Physiol Perform.* 2011;6:295-310.
- Ayala F, Calderón-López A, Delgado-Gosálbez JC, et al. Acute effects of three neuromuscular warm-up strategies on several physical performance measures in football players. *PLoS One.* 2017;12:e0169660.
- Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med.* 2005;39:324-329.
- Borg G. Psychophysical basis of perceived exertion. *Med Sci Sports Exerc.* 1982;14:377-381.
- Borresen J, Lambert MI. Quantifying training load: a comparison of subjective and objective methods. *Int J Sports Physiol Perform.* 2008;3:16-30.
- Bourdon PC, Cardinale M, Murray A, et al. Monitoring athletes training loads: consensus statement. *Int J Sports Physiol Perform.* 2017;12(suppl 2):S2161-S2170.
- Bustos A, Metral G, Cronin J, Uthoff A, Dolcetti J. Effects of warming up with lower-body wearable resistance on physical performance measures in soccer players over an 8-week training cycle. *J Strength Cond Res.* 2020;34:1220-1226.
- Campos-Vazquez MA, Mendez-Villanueva A, Gonzalez-Jurado JA, Leon-Prados JA, Santalla A, Suarez-Arrones L. Relationships between rating-of-perceived-exertion- and heart-rate-derived internal training load in professional soccer players: a comparison of on-field integrated training sessions. *Int J Sports Physiol Perform.* 2015;10:587-592.

10. Carroll TJ, Riek S, Carson RG. Neural adaptations to resistance training: implications for movement control. *Sports Med.* 2001;31:829-840.
11. Casamichana D, Castellano J, Calleja-Gonzalez J, San Roman J, Castagna C. Relationship between indicators of training load in soccer players. *J Strength Cond Res.* 2013;27:369-374.
12. Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Lawrence Erlbaum; 1988.
13. Cronin J, McNair PJ, Marshall RN. Velocity specificity, combination training and sport specific tasks. *J Sci Med Sport.* 2001;4:168-178.
14. Cronin JB, McNair PJ, Marshall RN. Is velocity-specific strength training important in improving functional performance? *J Sports Med Phys Fitness.* 2002;42:267-273.
15. Eston R. Use of ratings of perceived exertion in sports. *Int J Sports Physiol Perform.* 2012;7:175-182.
16. Feser EH, Macadam P, Nagahara R, Cronin J. The effects of lower limb wearable resistance on sprint-running step kinematics. *ISBS Proc Arch.* 2018;36:114-117.
17. Field AP, Gill N, Uthoff AM, Plews D. Acute metabolic changes with lower leg-positioned wearable resistances during submaximal running in endurance-trained runners. *Sports (Basel).* 2019;7:e220.
18. Foster C. Monitoring training in athletes with reference to overtraining syndrome. *Med Sci Sports Exerc.* 1998;30:1164-1168.
19. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15:109-115.
20. Gaudino P, Iaia FM, Strudwick AJ, et al. Factors influencing perception of effort (session rating of perceived exertion) during elite soccer training. *Int J Sports Physiol Perform.* 2015;10:860-864.
21. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med.* 2014;44(suppl 2):S139-S147.
22. Herman K, Barton C, Malliaras P, Morrissey D. The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Med.* 2012;10:75.
23. Hopkins WG. *A scale of magnitudes for effect statistics.* Accessed October 15, 2020. <https://www.sportsci.org/resource/stats/effectmag.html>
24. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009;41:3-13.
25. Hurst OK, Johnston M, Cronin J, Bezodis NE. Acute spatiotemporal and muscle excitation responses to wearable lower limb loading during maximal velocity sprinting. *ISBS Proc Arch.* 2018;36(1):106-109.
26. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol Perform.* 2019;14:270-273.
27. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc.* 2004;36:1042-1047.
28. Lau PWC, Wong DP, Chaouachi A, Coutts AJ, Chamari K, Luk TC. Advanced considerations in strength training: stretching, concurrent training and monitoring of training load. In: Kai JT, ed. *Strength Training: Types and Principles, Benefits and Concerns.* Nova Science; 2009:149-169.
29. Macadam P, Cronin JB, Uthoff AM, Feser EH. Effects of different wearable resistance placements on sprint-running performance. *Strength Cond J.* 2019;41:79-96.
30. Macadam P, Simperingham KD, Cronin JB. Forearm wearable resistance effects on sprint kinematics and kinetics. *J Sci Med Sport.* 2019;22:348-352.
31. McLaren SJ, Macpherson TW, Coutts AJ, Hurst C, Spears IR, Weston M. The relationships between internal and external measures of training load and intensity in team sports: a meta-analysis. *Sports Med.* 2018;48:641-658.
32. Morgans R, Orme P, Anderson L, Drust B. Principles and practices of training for soccer. *J Sport Health Sci.* 2014;3:251-257.
33. Osgnach C, Poser S, Bernardini R, Rinaldo R, di Prampero PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc.* 2010;42:170-178.
34. Scott BR, Lockie RG, Knight TJ, Clark AC, Janse de Jonge XA. A comparison of methods to quantify the in-season training load of professional soccer players. *Int J Sports Physiol Perform.* 2013;8:195-202.
35. Scott TJ, Black CR, Quinn J, Coutts AJ. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J Strength Cond Res.* 2013;27:270-276.
36. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ.* 2008;337:A2469.
37. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The importance of muscular strength: training considerations. *Sports Med.* 2018;48:765-785.
38. Troester JC, Jasmin JG, Duffield R. The influence of training load on postural control and countermovement jump responses in rugby union. *Sci Med Football.* 2019;3:320-325.
39. Yanci J, Iturri J, Castillo D, Pardeiro M, Nakamura FY. Influence of warm-up duration on perceived exertion and subsequent physical performance of soccer players. *Biol Sport.* 2019;36:125-131.

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